Quota Estimates for the 1998 Red Sea Urchin Fishery in British Columbia

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ABSTRACT

Campbell, A., D. Bureau, and D. Brouwer. 2000. Quota estimates for the 1998 red sea urchin fishery in British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2516: 31 p.

Annual landings of red sea urchin (*Strongylocentrotus franciscanus*) increased rapidly in the early 1980s for the south coast of British Columbia (B.C.) and in the late 1980s for the north coast, but subsequently were reduced and stabilized by arbitrary quotas. Coastwide landings were 6272 t valued at $12.4 M (Cdn.), with 109 licenses issued during 1996. Data from harvest logbooks indicated that there were no clear trends in annual CPUE (kilogram per diver hour) over the 1984-1996 period in each statistical area or general region in B.C. Bed areas were obtained by digitizing locations on charts indicated in harvest logbooks. Analyses of recent surveys and review of published survey reports provided estimates of density and mean weights allowing preliminary estimates of red sea urchin biomass in B.C. Recent published reports on growth rates indicate red sea urchin may grow at a slower rate and that natural mortality could be lower than previously reported. Assuming natural mortality rates between 0.05 and 0.10, and with estimated biomass, preliminary quota options were calculated between 2,673 t and 5,140 t for red sea urchins in B.C.. Further surveys for red sea urchin density, especially in the south coast of B.C., and more accurate estimates of red sea urchin bed areas, natural mortality and recruitment rates are required.

RÉSUMÉ

Campbell, A., D. Bureau, and D. Brouwer. 2000. Quota estimates for the 1998 red sea urchin fishery in British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2516: 31 p.

Les débarquements annuels d'oursin rouge (*Strongylocentrotus franciscanus*) ont augmenté rapidement au début des années 80 sur la côte Sud de la Colombie-Britannique et à la fin des années 80 sur la côte Nord, mais ils ont été réduits et stabilisés par l'allocation de quotas arbitraires. Pour l'ensemble de la côte, les débarquements se sont élevés à 6 272 t évaluées à 12,4 millions de dollars canadiens, avec 109 permis délivrés en 1996. D'après les données des journaux de pêche, on ne relevait aucune tendance claire des CPUE (nombre de kilogrammes par heure de plongée) annuelles entre 1984 et 1996 dans chacune des zones statistiques ou dans l'ensemble de la région en Colombie-Britannique. La superficie des gisements a été obtenue par numérisation sur cartes des emplacement indiqués dans les journaux de pêche. Les analyses des derniers relevés et l'examen des rapports publiés nous ont fourni des estimations de la densité et des poids moyens, ce qui a permis de formuler des estimations préliminaires de la biomasse d'oursin rouge en Colombie-Britannique. Les derniers rapports publiés sur les taux de croissance révèlent que l'oursin rouge peut se développer plus lentement et que la mortalité naturelle pourrait être plus faible que celle déjà signalée. En supposant un taux de mortalité compris entre 0,05 et 0,10, et d'après les estimations de la biomasse, on a calculé que les quotas préliminaires pourraient aller de 2 673 t à 5 140 t pour cette espèce en Colombie-Britannique. D'autres études sont nécessaires sur la densité des oursins rouges, en particulier sur la côte Sud, ainsi que des estimations plus précises de la superficie des gisements, de la mortalité naturelle et du taux de recrutement.

INTRODUCTION

A commercial dive fishery for the red sea urchin (*Strongylocentrotus franciscanus*) started during the 1970s in British Columbia (B.C.) (Fig. 1, 2, Table 1). Annual landings started to increase rapidly in the early 1980s for the south coast of B.C. and the late 1980s for the north coast, but subsequently were reduced and stabilized by arbitrary quotas (Fig. 3, Table 1). Coastwide landings were 6272 t valued at $12.4 M (Cdn.) with 109 licenses issued during 1996. The history of the management of this fishery is summarized in Campbell and Harbo (1991), Heizer *et al.* (1997), and Neifer (1998). A number of papers review various aspects of red sea urchin biology (Bernard and Miller 1973; Mottet 1976; Breen 1980; Sloan *et al.* 1987; Tegner 1989; Campbell and Harbo 1991; Botsford *et al.* 1993, 1994; Lai and Bradbury 1998; Ebert 1998). A few surveys to estimate standing stock of red sea urchins in B.C. during 1976-94 have been published (Breen *et al.* 1976, 1978; Adkins *et al.* 1981; Sloan *et al.* 1987; Jamieson *et al.* 1998a, 1998b, 1998c, 1998d). Based on the results of these surveys Campbell (1998) provided quota estimates for the 1995-96 red sea urchin fishery. Additional surveys for red sea urchin densities were conducted during 1995-97, the results of which are summarized in the present paper. Managers have requested additional biomass estimates based on the recent surveys so that quotas can be applied to the 1998 red sea urchin fishery in B.C.

The B.C. coast is divided into two main management areas, the 'North Coast' and the 'South Coast', and the South Coast is further divided into the inside waters of Vancouver Island (Inside Waters) and the west coast of Vancouver Island (WCVI) (Fig. 1). In addition, B.C. is subdivided into statistical areas and sub-areas for management and economic purposes (detailed charts are not shown in this paper).

The purpose of this paper is to (1) summarize catch and effort trends from the sales slips and harvest logbooks, (2) summarize the density surveys conducted to date and calculate preliminary estimates of biomass of red sea urchins, and (3) determine annual quotas for the red sea urchin fishery in B.C.

METHODS

CATCH AND EFFORT

Catch and effort data were obtained from sales slips and from harvest logbooks that fishers completed each day of fishing. Information from sales slips included total weight (pounds) and value (dollars) landed, CFV number, date and days fished. Information from the harvest logbooks included location of bed (with diagram), date, landed weight and minutes of diving. The harvest logbooks were not completed by each vessel so the data were used as a sample of catch per unit of effort (CPUE, kilograms per minute) only where both total catch (kg) and effort (minutes) per region were reported per diver for each area per day. Average daily vessel CPUE were calculated as the mean CPUE values per diver per day per vessel per area. Average annual CPUE per

statistical area were calculated from the average daily vessel CPUE values per statistical area. The statistical management areas were grouped for each general region as follows: North Coast (Areas 1 to 10, 102, 105, 106); Inside Waters (Areas 11 to 19, 28, 29); and WCVI (Areas 20 to 27, 123, 125). Average annual CPUE per region were calculated from mean daily vessel CPUE values per region.

BED AREAS

Commercial bed areas of red sea urchins were indicated on charts or diagrams provided by fishers with their harvest logbooks throughout B.C. during 1982-1996. The detailed bed areas were outlined on Hydrographic charts from 1- 9.1m (0-5 fm) below chart datum and were digitized and areas estimated. The digitized bed areas used in the analyses for this paper are those indicated as harvested during 1982-1996. Estimation of these red urchin bed areas must be treated with caution since the beds were not measured empirically in the field, and the proportion of the substrate types are unknown and may differ from one area to another.

DENSITY AND SIZE

Densities of red sea urchins were generally estimated within 1 m^2 quadrats along randomly chosen transects. Details of survey methodology varied between surveys (Breen *et al.* 1976, 1978; Adkins *et al.* 1981; Sloan *et al.* 1987; Jamieson *et al.* 1998a, 1998b, 1998c, 1998d). Density estimates from Adkins *et al.* (1981) could be biased since counts were made only at sites where there were more than 1 red sea urchin /m^2. Surveys of sea urchin density were also conducted during 1995 to 1997, using the methodology described by Jamieson and Schwarz (1998e). We reanalyzed the data from the 1994-97 surveys, except the 1993 data (Jamieson et al. 1998a), using the same methods of estimating mean densities as described by Jamieson and Schwarz (1998e). The estimated mean density, d (number / m^2), of all urchin sizes was calculated as

$$d = \frac{\sum_t c_t}{\sum_t a_t} \qquad (1)$$

The standard error of the mean density, se (d), was calculated as

$$se(d) = \sqrt{1 - n / N}\ \sqrt{\frac{\sum_t (c_t - d a_t)^2}{n(n-1)a^2}} \qquad (2)$$

where for each t^{th} transect, c_t = the number of red sea urchins observed in a transect, a_t = the area of transect surveyed in square metres, a = the mean transect area for all transects, n is the number of transects, and N is the total possible number of transects that can be sampled in the surveyed area. The expression $\sqrt{1 - n / N}$ was equal to one, because the sample size n was small compared to N.

Standard errors were not calculated for data that included the 1993 survey data since the survey method was different from surveys of later years. Where there were no density estimates for a statistical area, an overall mean density of 1.655 and 2.727 urchins /m^2 was used from all available data for the North Coast and the South Coast, respectively.

Test diameters (TD, in mm) of urchins were measured in the surveys by Jamieson *et al.* (1998a-1998d) but not by Adkins *et al.* (1981). Size frequencies for each area were used to estimate the proportion (P_h)of urchins that were of commercial size group h ($\geq$ 100 mm TD) and a general commercial size group h (100 - 140 mm TD) that fishers target for best quality gonad. The proportion of urchins in a size class was estimated as

$$P_h = \frac{\sum c_h}{\sum c_t} \qquad (3)$$

where c_h = the total number of urchins in size group h, then summed for all transects in a statistical area or sub-statistical area. Values of P_h were presented as percentages (100 P_h) in tables of this paper.

The density of the size group h was calculated as the product of d and P_h .

MEAN WEIGHTS

The relationship between total wet weight (g) (w_i) and test diameter (T_i) for size class i (at one mm increments) was determined from red sea urchins collected at Campbell River and WCVI (Tofino) (A. Campbell, unpublished data) (Fig. 1). The urchins were left out of water for about 4-6 hr before they were measured so that there would be some loss of water. The data were fitted to a linear regression log w_i = log a + b log T_i where a and b are constants estimated by least squares. A power equation was calculated:

$$w_i = aT_i^b \qquad (4)$$

where a = 0.0012659 and b = 2.7068 with r^2 = 0.960, sample size was 167 for all size classes (min. 10 to max. 150 mm TD).

Mean weights (W_h, in grams) of commercial-sized urchins for each area were estimated from the survey size frequency data as follows:

$$W_h = \frac{\sum_{i=1}^{x} (w_i X_i)}{X} \qquad (5)$$

where X_i = the number of urchins in size class i, X = total number of urchins of commercial size group h (≥ 100 mm TD or 100 - 140 mm TD), x = number of size classes (1 mm TD) in size group h, and w_i = the predicted wet weight (g) in size class i from equation (4).

BIOMASS ESTIMATION

Mean biomass per square metre (g / m^2), for each size group h, was calculated as

$$b_h = d\ P_h\ W_h \qquad (6)$$

Total current biomass of red sea urchins, for each size group, for various areas was calculated as

$$B_c = A\ d\ P_h\ W_h \qquad (7)$$

where B_c = current average biomass (g) converted to tonnes (10^6 g) and summed for each statistical subarea; A = commercial urchin bed area (m^2) estimated from digitized charts, subsequently converted to hectares (10,000 m^2 in a ha); W_h = estimated mean weight (g) of commercial-sized red sea urchins in size group h (TD ≥ 100 mm or 100 - 140 mm TD); d = estimated mean density (number per m^2) of red sea urchins of all sizes; P_h = proportion of urchins in size group h.

NATURAL MORTALITY

There are no published estimates of instantaneous natural mortality rate (M) for red sea urchins from northern B.C. Breen (1984) estimated that M ranged from 0.016 to 0.22 for red urchins from 3 sites in southern B.C. and considered a value between 0.1-0.2 to be acceptable. Woodby (1992) estimated M = 0.16 for red sea urchins from the Sitka, Alaska area. Botsford *et al.* (1993) estimated M = 0.14 for a population of red sea urchins in California. Lai and Bradbury (1998) estimated M to be about 0.16 for red sea urchins from Washington. Based on published values Campbell (1998) assumed M to be 0.15 in calculating quotas for the 1995 red sea urchin fishery in B.C. However, all these authors considered growth rates of red sea urchins to be faster (e.g., 4 - 6 yr to reach 100 mm TD) than that reported by Ebert (1998) who found tagged sea urchins from Washington and Oregon to take about 10 yr to reach 100 mm TD and 50 yr to reach 140 mm TD. Ebert (1998) calculated the mean instantaneous total mortality rate (Z yr^{-1}) of red sea urchins, from a total of twelve samples collected from six locations in Oregon and Washington, to be 0.052 (min. 0.016, max 0.133, lower 95% confidence interval (CI) 0.028, upper CI 0.076); equivalent to a mean annual survival rate of 0.949 (e^{-Z}). The average mortality values reported by Ebert (1998) are generally below those previously reported in the literature. Clearly M

will vary between areas and between size classes for red sea urchins in B.C. Although a similar tagging program on red sea urchins in B.C. has been conducted further experimental work is required to estimate growth of urchins < 2yr (5-30 mm TD) prior to final analysis and therefore the growth and mortality data of this program are not available for this paper. Consequently, for the purposes of this paper, a range of M values from 0.052 to 0.150 were considered for red sea urchins in B.C.

RECRUITMENT

Sloan *et al.* (1987) estimated recruitment to be highly variable between areas and to average about 9.5% of the total number of sea urchins in the size frequencies per area.

QUOTA ESTIMATION

A conservative management approach is used to estimate quotas (Q) for the red sea urchin fishery in B.C. A modified surplus production model is used to estimate a maximum sustainable yield (MSY) from a stock that is in the early stages of exploitation (Schaefer 1954; Gulland 1971). The model assumes that the MSY occurs when the maximum sustainable fishing mortality is equal to M.

$$Q = X\,M\,B_c \qquad (8)$$

where B_c is the current biomass, M is the instantaneous natural mortality rate and X = a correction factor to insure that a sustainable fishing mortality rate is well below the calculated MSY. The value of $X = 0.20$ was used in this paper and considered a reasonably conservative safeguard to account for errors in estimating the lower current biomass values (Caddy 1986; Garcia *et al.* 1989). The correction factor should provide for a conservative harvest per year in a developing fishery where little is known about the productivity of the population. Since equation 8 is derived from a Graham-Schaefer production model, recruitment is assumed to be unaltered by these low fishing levels. Although this approximation was developed for an unexploited virgin stock (Bo) we assumed that $B_c = B_o$. This is considered a conservative assumption since Bc probably underestimates Bo to some degree as fishing has already occurred.

Caution is required in the interpretation of these calculations for the quota because there are so many assumptions in the parameters used in the oversimplified model. Also there is considerable error in measuring densities, bed areas and mean weights which would yield large confidence limits (probably at least twice the mean above and below) around the current biomass estimates.

RESULTS AND DISCUSSION

CATCH AND EFFORT

The number of fishing vessels peaked at 116 in 1990 (Table 1). Coastwide landings peaked in 1992 (Tables 1 and 2, Fig. 2). Quotas have generally restricted landings in the South Coast since 1985 and in North Coast since 1993 (Table 1, Fig. 2, 3).

CPUE (kilograms per diver minute) from harvest logbooks was variable between years and statistical area (Table 3) and region (Fig. 4). There were no distinct general trends in CPUE at the general region level and statistical area level between 1982-1994 (Fig. 4, Appendix Figs. 1a-1c). The lack in CPUE trends suggests that either the fishery is at an early stage of development or CPUE data for red sea urchins can not be used to indicate fishery trends in B.C. Fishers have increased search time for high quality urchins in response to recent changes in market demands and the implementation of an individual quota scheme. Also, fishers may be maintaining high CPUE values by moving to unexploited sea urchin beds within a statistical area suggesting that CPUE would not decline until most the sea urchins were removed from most of the areas in the statistical area. Pfister and Bradbury (1996) suggested that divers maintained high landings of red sea urchins in Washington State by exploiting more distant and difficult fishing areas. There is a need to re-examine the distribution of effort and variability of CPUE data on a smaller spatial scale (*e.g.* statistical subarea or bed) than the statistical area level to determine whether CPUE is an appropriate index of red sea urchin abundance. How 'diver experience' influences CPUE in the red sea urchin fishery also should be examined from the harvest logbooks.

DENSITY AND MEAN WEIGHTS

Estimated mean densities (number / m^2), mean weights (g), and mean biomass (g / m^2) of commercial-sized red sea urchins ($\geq$ 100 mm TD or 100 - 140 mm TD) varied considerably between areas (Tables 4, 5, 6). The estimated total mean density of all size of red sea urchins was 1.655 for North Coast and 2.727 for the South Coast. The proportion and mean weights of individuals in the size group 100 - 140 mm TD was lower than those for $\geq$ 100 mm TD (Table 5). In areas where no size frequencies were available, size frequencies were combined for size group $\geq$ 100 mm TD and 100 - 140 mm TD, and an overall proportion of urchins was calculated as 0.3784 and 0.3584 for the North Coast and 0.5000 and 0.4500 for the South Coast, respectively, and overall mean weights estimated as 505.9 g and 479.5 g for the North Coast and 500.0 g and 480.0 g for the South Coast, respectively. The appropriate mean values were applied to statistical areas where no data were available.

Without having a standard methodology for all the surveys, estimating the standard error and upper and lower 95 % confidence limits for all estimated mean densities was difficult, suggesting that the mean densities and weights should be considered with caution.

As the fishery progresses, the average density and mean weight of the size group of urchins being exploited may decrease. Fishery-independent surveys of red sea urchin populations in heavily harvested areas should be repeated. Also temporal changes in size frequency and mean weights of commercial-sized individuals could be monitored by port sampling harvested red sea urchins.

BED AREAS

Estimated bed areas differed for each statistical area and increased by an average 20 % between 1994 and 1996 (Table 7). However, the total estimated bed area for the North Coast as of 1996 was 50,205.2 ha which was less than 50,977.8 ha estimated by Heritage and Campbell (1993) from all potential bed areas estimated by fishers.

Using charts to estimate bed areas is crude, especially as each location may have different substrate surface areas. The harvest logbooks provide an historical cumulative estimate of fishable sea urchin areas but may include a few areas that no longer have viable red sea urchin populations. There may be areas still unexplored, especially in the North Coast, that may contain substantial unfished "virgin" populations that have not been included in the biomass estimates. Bed area estimates probably provide the most uncertainty of all the estimates used to calculate biomass.

Annual records of log book bed area entries should be made on an annual basis rather than a cumulative basis on charts. Clear identification of beds in relation to the amount of red sea urchins removed from each bed needs to recorded more carefully by fishers and on grounds observers to allow detailed stock analyses on a bed by bed and/or sub-statistical area basis.

BIOMASS AND QUOTA

Red sea urchin biomass (B_c) differed considerably between areas (Table 8). Considering fishers may select sea urchins close to legal size for better gonad quality, the more appropriate quota estimate should be made from B_c calculated from the 100-140 mm TD size group. Choice of a conservative quota probably should be based on M values less than 0.10 which would suggest that the overall B.C. 1998 quota should be between 2,672.8 and 3,855.0 t. All these biomass and quota estimates must be treated with caution, especially when considering how inaccurate the bed estimates of viable red sea urchin populations may be.

Biomass was estimated from bed areas and urchin densities surveys between 0 and 9.1 meters chart datum because of logistics and diver safety issues. Although the majority of red sea urchins harvested was in this depth range, a small proportion of red sea urchins could be harvested in deeper areas. We assumed, that in general, red sea urchins deeper than 9.1 m provide an additional safety buffer for the overall population from exploitation.

Although we examined two alternative formulations, proposed by Garcia *et al* (1989) (i.e., their equations 7a and 8a, based on the Schaefer (1954) and Fox (1970) production models), to

estimate Q and MSY by including current yield (Y_c) in an exploited population, both formulae were unstable when attempting to obtain MSY estimates below Y_c. Garcia *et al* (1989) also indicated that these formulae are unstable under other conditions. Die and Caddy (1997) question whether any simple approximation method alone, in obtaining sustainable yield indicators from biomass estimates, can provide a safe yield target. They advocate use of low conservative targets for fishing mortality and several biological reference points as a precautionary approach. Lai and Bradbury (1998), through simulation of red sea urchin populations in Washington, suggested that target harvest rates should be well below biological references points such as $F_{max} = 0.48$ (fishing mortality at which Y/R is maximized) and $F_{0.1} = 0.19$ (at which slope of Y/R curve is 10% of the slope at origin) calculated from a yield per recruit model. In addition to resource monitoring, additional biological information on the variation in growth, mortality and recruitment rates is required for production modeling of red sea urchin populations in different areas of B.C.

If stock assessment and management is needed on a bed by bed and up to date basis, landings will be required in a timely way (within one year). A 3 (or longer) year periodic rotation of fishing grounds would provide for easier monitoring of the fishing fleet and landings and allow timely analysis of up to date landings data. Three or six year rotation of fishing grounds would also allow recovery of the harvestable stock through recruitment and growth. Caddy and Seijo (1998) suggested that for fast-growing and long-lived species with $M = 0.1$ a four-year rotation fishing schedule could achieve optimal biomass. Botsford *et al.* (1993) and Lai and Bradbury (1998) consider periodic harvest schedules (rotation), although not increasing cumulative yield, are biologically beneficial, reduce variability of yield, risk, and probably management and enforcement costs.

RECOMMENDATIONS

(1) Biomass and quota estimates in this paper should be considered only as a preliminary indication of the status of red sea urchin stocks in B.C.

(2) Further surveys to estimate density and growth, mortality and recruitment rates of red sea urchins in B.C. are required to assist with production modeling.

(3) More accurate estimates of bed areas holding viable populations of red sea urchins are required.

(4) A 3 (or longer) year periodic rotation of red sea urchin fishing grounds should be considered (a) for easier monitoring of the fishing fleet and landings and allowing timely analysis of up to date landings data, and (b) to allow recovery of the harvestable stock through recruitment, growth and redistribution of individuals.

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Table 1. Annual red sea urchin landings (tonnes), value and effort for British Columbia, 1978-96, as reported on sales slips and harvest logs.

Year	Type and Number of Licenses issued	South Coast [1] Quota (t)	North Coast Quota (t)	Number of Vessels with Landings	Total Vessel Fishing Days	Coastwide Landings (t)	Landed Value ($.10^3$)	Whole Landed Value ($/t)	Mean CPUE [2] (t/vessel day)	Mean CPUE [3] (kg/diver hr)
1978	C			4	54	75	16	213	1.4	-
1979	C			29	298	317	76	240	1.1	-
1980	C			18	331	333	84	252	1.0	-
1981	C	136		18	127	116	34	293	0.9	-
1982	C			21	195	160	56	350	0.8	-
1983	Z 64			36	825	986	358	354	1.2	311
1984	Z 85			47	1150	1764	712	403	1.6	281
1985	Z 86	1803		46	1086	1815	764	419	1.7	360
1986	Z 103	1500		67	1534	2067	1011	455	1.4	363
1987	Z 184	1633		97	1807	2118	1148	541	1.2	325
1988	Z 184	1678		84	1249	2116	1241	587	1.7	296
1989	Z 240	1644		109	1542	2658	1631	614	1.7	360
1990	Z 188	1668		116	2651	3158	1953	618	1.2	298
1991	Z 102	1531		89	3862	6831	4187	613	1.8	363
1992	Z 108	1554		110 [4]	5789	12983	8002	616	2.1	388
1993	Z 107	1401	5400	103	3204	6264	5271	841	1.9	340
1994	Z 110	1543	5897	98	3979	5818	7849	1349	1.5	325
1995	Z 108	1386.8	5454.5	108	4133	6590	11269	1710	1.6	325
1996	Z 109	1264.7	5359.7	109	3766	6272	12384	1974	1.7	340

[1] South Coast quota includes exploratory areas, North Coast quota was new in 1993.
[2] From sales slip data.
[3] CPUE from harvest logbook data.
[4] Larger than the number of licenses issued due to license transfers.

Table 2. Summary of annual red sea urchin landings (tonnes) from sales and validation slips in British Columbia by region and statistical area during 1982-96.

REGION	STAT AREA	YEAR															TOTAL
		82	83	84	85	86	87	88	89	90	91	92	93	94	95[1]	96[1]	
North Coast	001			2.2					0.2				96.8	232.3	244.7	252.4	828.6
	002								223.0	37.3	335.8	1111.0	275.9	548.2	594.0	570.8	3696.0
	003								1.6	24.5	184.7	1.0	127.2	203.5	40.7	67.0	650.2
	004						23.0	73.0	116.0	156.8	1085.1		1008.0	720.3	899.7	816.5	4898.4
	005							11.0	1.3	265.3	2581.3	3294.0	463.0	943.5	1238.0	1106.4	9903.8
	006 *							7.3	168.4	67.1	97.6	4063.0	2103.0	1134.2	995.8	1195.0	9831.4
	007						179.0	314.0	217.0	1040.1	758.6	2763.0	1012.0	757.6	1017.6	796.4	8855.3
	008						91.0	32.0	65.0		124.1	140.0	35.8	62.0	112.6	112.5	775.0
	009										30.2	114.0		54.9	46.2	16.8	262.1
	010					12.0			180.0		296.3	38.0	242.5	182.1	224.4	230.6	1405.9
	Total			2.2		12.0	293.0	437.3	972.5	1591.1	5493.7	11524.0	5364.2	4838.6	5413.7	5164.4	41106.7
Inside Waters	011		7.8	0.3		27.0	6.9	2.6		84.8	36.4	8.0	55.6	15.7	44.9	44.2	334.2
	012	2.5	99.0	437.0	354.0	548.0	420.0	534.0	569.0	437.6	358.7	531.0	329.0	386.2	359.6	394.3	5759.9
	013		264.0	777.3	492.0	376.0	491.0	480.0	493.0	428.4	370.7	320.0	184.0	203.8	230.1	243.6	5353.9
	014	46.0	260.0	172.0	167.0	178.0	193.0	78.0	122.0	56.6				0.5			1273.1
	015				106.0	56.0	32.4	21.0	6.7	1.2	8.6			4.7			236.6
	016				5.9	4.4		2.3		0.6							13.2
	017	0.8	59.0	33.0	29.0	57.0	71.0		9.0	43.0	26.6	103.0	21.0	2.6	20.0	21.1	496.1
	018	11.0	38.0	67.4	48.0	129.0	71.0	22.0	64.0	46.5	94.8	36.0	102.1	41.4	65.3	108.4	944.9
	019	94.0	112.0	76.3	77.0	105.0	123.0	78.0	57.0	58.6	27.2	86.0	16.3	50.0	47.6	3.0	1011.0
	028						16.8			0.3							17.1
	029			5.7	47.0	2.0	7.8		1.6	1.8	14.1	4.0			22.4	24.3	130.7
	Total	154.3	839.8	1569.0	1325.9	1482.4	1432.9	1217.9	1322.3	1159.4	937.1	1088.0	708.0	705.0	789.9	838.9	15570.8
WCVI	020		24.0	69.1	29.8	40.0	17.0	74.0	15.0	7.9	31.2	56.0	14.6	15.0	32.8	17.5	443.9
	021										2.7	9.0					11.7
	023 **		22.0	17.3	96.0	154.0	63.0	13.0		59.7	58.4	31.0	43.4	24.8	53.1	44.4	680.1
	024	5.0	38.0	103.0	158.0	283.8	199.0	250.0	223.0	215.1	185.1	200.0	92.0	112.2	202.4	122.6	2389.2
	025 ***				145.0		95.0	66.0	39.0	56.8	115.8	10.0	7.0	52.1			586.7
	026		62.0	3.9	15.0	2.5	8.3						2.0				93.7
	027				45.0	91.0	12.0	58.0	86.0	68.1	121.1	65.0	50.0	75.8	91.2	73.9	837.1
	Total	5.0	146.0	193.3	488.8	571.3	394.3	461.0	363.0	407.6	514.3	371.0	209.0	279.9	379.5	258.4	5042.4
South Coast	Total	159.3	985.8	1762.3	1814.7	2053.7	1827.2	1678.9	1685.3	1567.0	1451.4	1459.0	917.0	984.9	1169.4	1097.3	20613.2
All Areas in B.C.	Total	159.3	985.8	1764.5	1814.7	2065.7	2120.2	2116.2	2657.8	3158.1	6945.1	12983.0	6281.2	5823.6	6583.1	6261.7	61720.0

* includes sales slips from stat area 106
** includes sales slips from stat area 123
*** includes sales slips from stat area 125
[1] from D&D validation slips

Table 3. Summary of mean catch per unit effort (kg per min) of red sea urchins by statistical area, from harvest log books, 1982 - 1996

REGION	STAT AREA	YEAR															ALL YEARS
		82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	
North Coast	001								3.8				7.6	4.3	5.6	7.1	5.7
	002								5.9	8.7	7.0	7.5	6.3	5.4	5.2	7.3	6.7
	003								8.0		6.1		3.3	5.4	4.0	6.0	5.5
	004							5.4	6.1	4.7	5.4		6.4	5.2	5.1	5.2	5.5
	005 [1]							4.0	3.5	4.7	6.3	5.7	6.4	5.7	5.1	6.3	5.3
	006 [2]							5.2	5.2	6.3	5.9	7.0	5.6	6.6	5.4	6.2	5.9
	007						5.8	4.7	5.3	5.0	5.1	5.1	5.7	5.1	5.8	6.4	5.4
	008						5.5	5.0	8.4		5.5	6.4		4.7	5.3	6.3	5.9
	009										5.0	8.9	2.8	4.5	4.2	4.6	5.0
	010							4.0	7.2		7.1		4.4	4.4	5.2	7.2	5.6
	Total Mean						5.8	5.1	6.1	5.0	6.2	6.5	5.8	5.1	5.5	6.1	5.7
Inside Waters	011			2.6		8.0		4.5		4.7	6.5	5.6	6.4	4.0	6.4	5.6	5.4
	012		5.6	3.4	8.4	7.0	6.6	5.5	5.3	5.4	7.2	7.5	6.0	7.0	6.3	5.0	6.2
	013		5.2	4.7	5.8	6.6	5.6	3.7	5.5	5.0	6.8	7.7	6.4	5.5	4.4	5.9	5.6
	014	1.1	3.0	5.2	5.3	7.1	7.9	5.3	5.6	6.0		6.1					5.3
	015				5.6	4.4	5.2	3.8	[illegible]	2.2	2.9						4.0
	016				7.6	2.6		5.0		1.9							4.3
	017			4.6	3.7	6.4	3.7	5.6		4.5	7.8	5.4	8.2	4.7	5.8	4.9	5.4
	018		4.2	4.7	3.4	6.3	4.1	3.7	4.7	5.7	6.1	4.0	5.9	4.7	5.0	5.9	4.9
	019	4.8	3.7	4.1	5.2	7.6	5.0	4.4	4.1	4.3	6.8	4.9	3.3	5.2	4.3	4.0	4.8
	029			5.8		7.3		4.5			9.4	4.5	7.0	3.8	6.7	4.5	6.0
	Total Mean	2.9	5.0	5.6	6.1	6.5	5.6	4.8	5.4	5.3	6.6	6.8	5.8	5.6	5.1	5.6	5.5
WCVI	020		3.1	4.4	7.3	5.5	1.8	4.9	3.9	4.8	5.6	5.1	5.0	4.5	4.8	4.2	4.6
	023 [3]		4.7	3.2	5.3	4.2	5.7	6.7		5.2	8.6	6.6	5.2	4.7	5.1	5.6	5.5
	024 [4]	4.3	3.0	4.8	4.2	5.9	5.3	5.7	4.2	4.8	5.8	8.6	5.0	4.8	6.7	6.9	5.3
	025 [5]				4.2		4.7	4.0	6.4	5.6	5.9	6.5	5.1	4.4			5.2
	026		4.5	3.2	8.1	5.6	4.2	3.3									4.8
	027				4.8	5.9	6.0	6.0	5.9	5.6	7.3	7.5	4.7	4.7	5.2	5.8	5.8
	Total Mean	4.3	4.0	4.3	5.1	5.5	5.1	5.1	6.2	5.0	6.2	7.0	5.1	4.8	5.8	5.8	5.3

[1] incorporates the data from statistical area 105
[2] incorporates the data from statistical area 106
[3] incorporates the data from statistical area 123
[4] incorporates the data from statistical area 124
[5] incorporates the data from statistical area 125

Table 4. Published total density estimates of red sea urchins for South Coast.

Location	Statarea	Date	Urchin Density Number / m^2
Breen *et al.* (1978)			
Site #2, S. Vargas I.	24	Nov. 1977	5.7
Site #3, Thorn Reef	24	Nov. 1977	9.6
Site #3, Thorn Reef	24	Aug. 1974	4.8
Site #3, Thorn Reef	24	Jun. 1976	5.6
Breen *et al.* (1976)			
S. Vargas I.	24	Jun. 1976	12.6
Adkins *et al.* (1981)			
80-93, Nose Point	18	Nov. 1980	4.32
80-95, Ballingall Islts	18	Nov. 1980	1.68
80-96, Wilmont Head	18	Nov. 1980	1.59
80-97, S. Parker I.	18	Nov. 1980	1.5
80-98, Phillmont Pt.	18	Nov. 1980	4.41
80-100, Beaver Pt.	18	Nov. 1980	3.24
80-101, Yeo Pt.	18	Nov. 1980	1.5
80-102, Channel I.	18	Nov. 1980	5.84
80-104, Active Pass	18	Nov. 1980	1.86
80-105, Active Pass	18	Nov. 1980	5.8
80-108, Rock N. Secret I.	18	Nov. 1980	9.76
80-114, Conconi Reef	18	Nov. 1980	1.77
80-118, Kendrick Rock	17	Nov. 1980	2.83
80-120, Gabriola Pass	17	Nov. 1980	3.59
80-121, Gabriola Pass	17	Nov. 1980	4.04
80-122, Portland Island	19	Nov. 1980	2.88
80-123, Portland Island	19	Nov. 1980	1.20
80-127, Dock I.	19	Nov. 1980	2.43
80-128, Pelorus Pt.	19	Nov. 1980	3.48
80-129, Pt. Fairfax	19	Nov. 1980	1.43
80-130, Brethour I.	19	Nov. 1980	1.0
80-132, Gooch I.	19	Nov. 1980	2.63
80-133, N. Cod Rock	19	Nov. 1980	7.76
80-134, Forrest I.	19	Nov. 1980	3.85
80-135, Halibut I.	19	Nov. 1980	1.59
80-137, Little D'arcy I.	19	Nov. 1980	4.27
80-138, Little D'arcy I.	19	Nov. 1980	0.1
Sloan *et al.* (1987)			
Gabriola Pass-Site 101	17	Oct 84-Feb 85	7.0
Gabriola Pass- Site 102	17	Oct 84-Feb 85	1.6
Gabriola Pass- Site 103	17	Oct 84-Feb 85	2.1
Gabriola Pass- Site 104	17	Oct 84-Feb 85	8.3
Hornby I.- Site 201	14	Oct 84-Feb 85	3.1
Hornby I.- Site 202	14	Oct 84-Feb 85	0.9
Hornby I.- Site 203	14	Oct 84-Feb 85	3.2
Hornby I.- Site 204	14	Oct 84-Feb 85	4.6
Hornby I.- Site 205	14	Oct 84-Feb 85	9.6
Tofino- Site 302	24	Oct 84-Feb 85	4.4
Total Mean			4.0

Table 5. Summary of estimated mean density (number/m^2), mean weight (g) and mean biomass (g/m^2) of red sea urchins in British Columbia, by substatistical area, obtained from broad-brush surveys during 1993 - 1997. Data include analyses from Jamieson et al. (1998a, b, c, d) and present study. Mean biomass = density x mean weight. NQCI, EQCI and WQCI refer to north, east and west areas of the Queen Charlotte Islands.

Statarea	Year	Survey	Total Transect		Total Urchin			Percent Urchins		Number	Urchin density		Mean weight (g)		Mean biomass (g/m^2)	
			Number	Length (m)	number	density mean	density se	≥ 100 mm TD	100 - 140 mm TD	of Urchins Measured	≥ 100 mm T	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD
North coast of B.C.																
1.001	94	NQCI	5	764.0	2663	3.486	0.828	46.62	45.55	281	1.625	1.588	502.8	490.7	817.1	779.1
1.002	94	NQCI	15	1686.0	9371	5.558	0.952	48.96	47.57	1009	2.721	2.644	500.1	486.5	1360.9	1286.5
1.003	94	NQCI	16	1795.0	2796	1.558	0.413	72.09	60.44	455	1.123	0.941	651.0	589.0	731.0	554.5
1.007	94	NQCI	9	2859.0	2252	0.788	0.311	70.86	59.67	429	0.558	0.470	618.8	555.5	345.4	261.1
2.003	93	EQCI	5	556.7	509	0.914		46.25	46.25	80	0.423	0.423	523.4	523.4	221.3	221.3
2.007	93	EQCI	6	476.0	1609	3.380		28.14	26.55	501	0.951	0.897	523.7	499.0	498.3	447.8
2.008	93	EQCI	7	1070.3	1836	1.715		31.04	29.81	567	0.532	0.511	513.0	497.6	273.2	254.4
2.010	93	EQCI	4	557.4	446	0.800		52.36	46.35	233	0.419	0.371	626.5	588.7	262.5	218.4
2.011	93	EQCI	8	589.0	1510	2.564		33.16	30.57	579	0.850	0.784	544.7	501.5	463.1	393.0
2.012	93	EQCI	6	3234.0	462	0.143		52.00	52.00	75	0.074	0.074	485.7	485.7	36.1	36.1
2.013	93	EQCI						31.11	28.89	90			532.8	506.0		
2.014	93	EQCI	9	1047.3	2094	1.999		23.44	23.44	320	0.469	0.469	478.6	478.6	224.3	224.3
2.015	93	EQCI	6	229.6	202	0.880		34.92	29.90	398	0.307	0.263	602.9	542.9	185.3	142.8
2.017	93	EQCI	11	628.5	1760	2.800		40.50	38.41	479	1.134	1.076	517.2	495.0	586.6	532.5
2.018	95	EQCI	11	934.0	2196	2.351	0.952	34.90	34.45	447	0.821	0.810	475.7	469.9	390.3	380.6
2.019	95	EQCI	5	711.0	1414	1.989	0.958	34.88	33.72	172	0.694	0.671	489.6	476.1	339.7	319.3
2.031	95	WQCI	5	534.0	1562	2.925	0.984	29.97	23.34	287	0.877	0.683	630.4	530.9	552.5	362.5
2.033	95	WQCI	4	240.0	512	2.133	2.164	19.69	19.69	127	0.420	0.420	458.8	458.8	192.7	192.7
2.036	95	WQCI	5	348.0	872	2.506	1.327	37.89	35.79	190	0.950	0.897	553.3	531.6	525.4	476.7
2.049	93	WQCI	2	642.4	255	0.397		15.25	15.25	118	0.061	0.061	489.8	489.8	29.7	29.7
2.050	93	WQCI	2	70.2	282	4.019		30.21	30.21	96	1.214	1.214	438.8	438.8	532.7	532.7
2.051	93	WQCI						11.01	11.01	109			409.3	409.3		
2.053	93	WQCI	1	93.0	422	4.540		29.70	29.70	165	1.348	1.348	421.7	421.7	568.6	568.6
2.055	93	WQCI	1	25.7	77	2.994		13.37	10.47	172	0.400	0.313	559.8	440.7	224.1	138.1
2.059	93	WQCI	5	311.7	284	0.911		9.84	9.84	122	0.090	0.090	425.2	425.2	38.1	38.1
2.060	93	WQCI	3	385.5	699	1.813		4.82	4.82	166	0.087	0.087	416.9	416.9	36.4	36.4
2.063	93	WQCI	6	207.4	2080	10.031		11.27	11.27	71	1.130	1.130	373.1	373.1	421.7	421.7
2.064	93	WQCI	2	52.4	194	3.706		7.40	7.40	419	0.274	0.274	404.1	404.1	110.8	110.8
2.066	93	WQCI	5		346			18.46	18.18	363			450.7	444.9		

Table 5. Summary of estimated mean density (number/m^2), mean weight (g) and mean biomass (g/m^2) of red sea urchins in British Columbia, by substatistical area, obtained from broad-brush surveys during 1993 - 1997. Data include analyses from Jamieson et al. (1998a, b, c, d) and present study.
Mean biomass = density x mean weight. NQCI, EQCI and WQCI refer to north, east and west areas of the Queen Charlotte Islands.

Statarea	Year	Survey	Total Transect		Total Urchin			Percent Urchins		Number	Urchin density		Mean weight (g)		Mean biomass (g/m^2)	
			Number	Length (m)	number	density mean	density se	≥ 100 mm TD	100 - 140 mm TD	of Urchins Measured	≥ 100 mm T	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD
2.067	93	WQCI	3		522			38.38	31.89	185			560.6	470.1		
2.068	95	WQCI	3	242.0	1786	7.380	3.508	12.03	12.03	291	0.888	0.888	411.0	411.0	364.8	364.8
2.069	95	WQCI	2	145.0	0	0.000	0.000				0.000	0.000			0.0	0.0
2.071	95	WQCI	2	110.0	996	9.055	1.464	15.32	15.32	111	1.387	1.387	410.3	410.3	568.9	568.9
2.074	95	WQCI	1	190.0	680	3.579		34.15	34.15	82	1.222	1.222	403.6	403.6	493.2	493.2
2.075	95	WQCI	3	266.0	1101	4.139	2.156	23.32	23.32	313	0.965	0.965	458.7	458.7	442.8	442.8
2.078	95	WQCI	2	65.0	0	0.000	0.000				0.000	0.000			0.0	0.0
2.079	95	WQCI	4	459.0	1430	3.115	1.190	26.92	26.92	78	0.839	0.839	479.1	479.1	401.9	401.9
2.080	95	WQCI	1	89.0	712	8.000		13.95	13.95	43	1.116	1.116	405.2	405.2	452.4	452.4
3.001	93	Tsimshian	29	1011.2	1627	1.609		46.81	43.88	989	0.753	0.706	541.8	514.2	408.1	363.0
3.002	93	Tsimshian	6	211.8	119	0.562		55.02	49.34	229	0.309	0.277	578.2	543.7	178.8	150.8
4.001	93	Tsimshian	34	1264.4	1414	1.118		52.48	47.21	968	0.587	0.528	575.0	531.6	337.5	280.7
4.002	93	Tsimshian	8	809.4	685	0.846		52.50	46.11	360	0.444	0.390	569.9	521.6	253.2	203.5
4.002	95	StephensIs	38	2566.0	6208	2.419	0.496	42.05	37.21	1075	1.017	0.900	565.4	508.4	575.2	457.6
4.009	95	StephensIs	22	3677.0	2084	0.567	0.273	43.08	41.52	448	0.244	0.235	513.4	494.0	125.4	116.2
4.013	93	Tsimshian	3	26.5	77	2.903		43.84	39.73	73	1.273	1.153	537.3	490.3	683.9	565.5
5.011	97	BanksIs	6	912.0	408	0.447	0.252	35.61	31.06	132	0.159	0.139	546.4	495.2	87.0	68.8
5.013	97	BanksIs	3	396.0	236	0.596	0.405	64.71	44.12	68	0.386	0.263	664.9	507.6	256.4	133.5
5.020	97	BanksIs	25	2540.0	9040	3.559	0.602	47.67	42.27	2058	1.697	1.505	553.9	498.7	939.8	750.3
5.021	97	BanksIs	22	2436.0	4354	1.787	0.419	49.62	42.75	393	0.887	0.764	563.1	495.6	499.4	378.7
6.010	94	CampanaIs	27	4753.0	9895	2.082	0.340	44.85	41.09	825	0.934	0.855	536.6	499.0	501.0	426.8
6.012	94	CampanaIs	7	524.0	676	1.290	0.602	32.41	28.70	108	0.418	0.370	561.2	518.8	234.6	192.1
6.013	93	Kitasoo	32	2434.2	7641	3.139		38.46	36.38	2306	1.207	1.142	507.6	480.7	612.8	549.0
6.014	93	Kitasoo	11	761.6	2008	2.636		43.32	38.92	794	1.142	1.026	560.4	504.8	640.1	518.0
6.015	93	Kitasoo	8	425.6	571	1.342		47.75	45.67	289	0.641	0.613	510.6	486.8	327.1	298.3
6.016	93	Kitasoo	11	881.2	2225	2.525		27.68	27.27	737	0.699	0.689	442.7	435.6	309.4	300.0
6.016	95	PriceIs	29	1545.0	5046	3.266	0.613	26.18	25.49	867	0.855	0.833	490.6	478.4	419.5	398.3
6.017	93	Kitasoo	9	520.5	3456	6.640		44.24	42.74	868	2.938	2.838	484.8	468.0	1424.0	1328.2
6.017	95	PriceIs	7	487.0	678	1.392	0.746	32.02	30.90	178	0.446	0.430	566.4	555.2	252.5	238.8
6.018	93	Kitasoo	3	315.8	161	0.510		45.28	45.28	53	0.231	0.231	444.5	444.5	102.6	102.6

Table 5. Summary of estimated mean density (number/m^2), mean weight (g) and mean biomass (g/m^2) of red sea urchins in British Columbia, by substatistical area, obtained from broad-brush surveys during 1993 - 1997. Data include analyses from Jamieson et al. (1998a, b, c, d) and present study. Mean biomass = density x mean weight. NQCI, EQCI and WQCI refer to north, east and west areas of the Queen Charlotte Islands.

			Total Transect		Total Urchin			Percent Urchins		Number	Urchin density		Mean weight (g)		Mean biomass (g/m^2)	
Statarea	Year	Survey	Number	Length (m)	number	density mean	se	≥ 100 mm TD	100 - 140 mm TD	of Urchins Measured	≥ 100 mm T	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD
6.019	93	Kitasoo	6	566.3	831	1.467		30.77	30.77	299	0.452	0.452	419.5	419.5	189.4	189.4
7.001	97	Goose	15	1244.0	160	0.129	0.063	5.00	5.00	80	0.006	0.006	459.5	459.5	3.0	3.0
7.002	93	Kitasoo	4	268.0	1635	6.102		30.35	29.11	481	1.852	1.776	479.4	462.2	887.9	820.8
7.003	93	Kitasoo	14	2085.9	6156	2.951		37.21	36.84	1618	1.098	1.087	469.4	464.5	515.4	504.9
7.004	93	Kitasoo	4	916.3	1420	1.550		39.66	38.83	358	0.615	0.602	480.5	468.3	295.4	281.8
7.008	93	Heiltsuk	5	3016.3	1038	0.344		30.82	30.82	146	0.106	0.106	452.1	452.1	47.9	47.9
7.009	93	Heiltsuk						41.61	41.29	310			466.5	463.4		
7.018	93	Heiltsuk	13	1055.0	2277	2.158		27.00	26.39	811	0.583	0.570	465.8	445.2	271.5	253.6
7.018	94	Heiltsuk	26	1458.0	4988	3.421	0.827	30.59	30.07	765	1.046	1.029	459.6	450.4	481.0	463.3
7.018	95	Heiltsuk	36	2168.0	6780	3.127	0.431	31.80	30.76	1154	0.995	0.962	472.2	456.7	469.6	439.4
7.018	96	Heiltsuk	58	5023.0	21040	4.189	0.516	45.64	44.42	1308	1.912	1.861	472.8	460.6	903.9	857.1
7.018	97	Goose	23	1230.0	4400	3.577	0.517	31.16	30.94	1797	1.115	1.107	444.9	441.6	495.9	488.7
7.020	93	Heiltsuk	4	471.2	1190	2.525		20.50	20.50	200	0.518	0.518	418.3	418.3	216.5	216.5
7.023	94	Heiltsuk	1	36.0	0	0.000					0.000	0.000			0.0	0.0
7.025	93	Heiltsuk	11	26343.0	4619	0.175		27.40	26.73	1040	0.048	0.047	480.9	467.3	23.1	21.9
7.025	94	Heiltsuk	26	1286.0	3726	2.897	0.634	41.05	40.10	631	1.189	1.162	489.4	472.2	582.0	548.6
7.025	95	Heiltsuk	28	1902.0	2556	1.344	0.427	36.02	35.13	669	0.484	0.472	457.5	442.6	221.5	208.9
7.025	97	Goose	29	2738.0	136	0.050	0.043	31.34	31.34	67	0.016	0.016	423.7	423.7	6.6	6.6
7.026	95	Heiltsuk	7	805.0	0	0.000	0.000				0.000	0.000			0.0	0.0
7.026	97	Goose	7	449.0	10	0.022	0.013	0.00	0.00	0	0.000	0.000			0.0	0.0
7.027	93	Heiltsuk	8	838.4	1431	1.707		25.73	25.28	447	0.439	0.431	440.2	431.4	193.3	186.1
7.031	93	kitasoo	10	1025.8	3200	3.119		42.26	41.62	937	1.318	1.298	473.6	467.2	624.4	606.7
7.031	95	Pricels	32	1396.0	5534	3.964	0.941	26.01	25.79	915	1.031	1.022	436.9	433.4	450.5	443.1
7.032	93	Heiltsuk	4	729.6	1923	2.636		21.95	21.95	401	0.578	0.578	436.5	436.5	252.5	252.5
8.002	93	Heiltsuk						26.34	25.45	448			482.5	465.7		
10.001	93	Heiltsuk	5	2984.0	2097	0.703		12.35	12.23	826	0.087	0.086	438.0	431.0	38.0	37.0
106.002	94	Campanials	28	2633.0	11970	4.546	0.703	38.79	37.90	1124	1.763	1.723	475.8	458.3	839.0	789.7

Table 5. Summary of estimated mean density (number/m^2), mean weight (g) and mean biomass (g/m^2) of red sea urchins in British Columbia, by substatistical area, obtained from broad-brush surveys during 1993 - 1997. Data include analyses from Jamieson et al. (1998a, b, c, d) and present study. Mean biomass = density x mean weight. NQCI, EQCI and WQCI refer to north, east and west areas of the Queen Charlotte Islands.

Statarea	Year	Survey	Total Transect		Total Urchin			Percent Urchins		Number	Urchin density		Mean weight (g)		Mean biomass (g/m^2)	
			Number	Length (m)	number	density mean	density se	≥ 100 mm TD	100 - 140 mm TD	of Urchins Measured	≥ 100 mm T	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD
South Coast of B.C.																
11.002	96	QCStrait	32	1360.0	4248	3.124	0.621	66.15	51.87	455	2.066	1.620	674.8	597.1	1394.4	967.4
12.003	94	QCStrait	9	309.0	623	2.016	0.619	80.77	60.77	130	1.628	1.225	690.6	588.6	1124.6	721.2
12.004	94	QCStrait	1	25.0	0	0.000					0.000	0.000			0.0	0.0
12.005	94	QCStrait	10	402.0	549	1.366	0.192	91.16	61.90	147	1.245	0.845	750.1	638.9	933.9	540.1
12.006	94	QCStrait	16	1356.0	479	0.353	0.126	77.78	56.41	117	0.275	0.199	705.1	588.3	193.7	117.2
12.007	95	QCStrait	6	224.0	135	0.603	0.168	97.04	64.44	135	0.585	0.388	751.0	630.0	439.2	244.7
12.008	94	QCStrait	4	485.0	356	0.734	0.321	51.35	32.43	37	0.377	0.238	699.2	554.2	263.5	131.9
12.011	94	QCStrait	15	713.0	2176	3.052	0.798	38.93	35.66	429	1.188	1.088	550.3	510.0	653.7	555.1
12.012	94	QCStrait	2	69.0	447	6.478	2.657	27.10	27.10	107	1.756	1.756	499.0	499.0	876.2	876.2
12.013	95	QCStrait	21	1316.0	1207	0.917	0.371	64.06	51.60	1188	0.588	0.473	654.0	583.4	384.3	276.1
12.013	96	QCStrait	11	332.0	1700	5.120	1.193	62.92	55.62	178	3.222	2.848	588.5	544.8	1896.1	1551.5
12.015	94	QCStrait	2	57.0	341	5.982	5.523	36.84	36.84	57	2.204	2.204	427.2	427.2	941.7	941.7
12.016	94	QCStrait	20	1658.0	833	0.502	0.169	63.87	52.94	119	0.321	0.266	642.5	563.0	206.0	149.6
12.017	94	QCStrait	2	443.0	0	0.000	0.000				0.000	0.000			0.0	0.0
12.018	94	QCStrait	17	971.0	1423	1.465	0.384	61.92	57.53	365	0.907	0.843	559.8	531.4	508.0	448.1
12.019	94	QCStrait	3	258.0	118	0.457	0.445	41.38	31.03	29	0.189	0.142	626.7	547.5	118.6	77.7
12.020	94	QCStrait	1	59.0	209	3.542		79.17	50.00	24	2.804	1.771	720.9	614.0	2021.8	1087.4
12.021	94	QCStrait	2	93.0	202	2.172	0.176	73.53	70.59	34	1.597	1.533	581.6	563.3	928.8	863.7
12.026	94	QCStrait	1	52.0	32	0.615										
12.036	94	QCStrait	1	83.0	0	0.000					0.000	0.000			0.0	0.0
12.039	94	QCStrait	10	576.0	45	0.078	0.071	100.00	100.00	5	0.078	0.078	541.3	541.3	42.3	42.3
12.039	95	QCStrait	15	1183.0	82	0.069	0.037	96.47	50.59	85	0.067	0.035	829.2	685.4	55.4	24.0
12.041	95	QCStrait	7	200.0	148	0.740	0.275	91.84	38.78	147	0.680	0.287	863.0	668.1	586.5	191.7
12.014	96	CapeSutil	8	809.0	4532	5.602	4.204	37.41	36.05	147	2.096	2.020	464.9	450.1	974.3	909.1
111.000	96	Cox Isl.	6	598.0	8180	13.679	2.376	30.26	29.74	380	4.140	4.068	452.6	444.7	1873.7	1809.1

Table 6. Summary of estimated mean density (number/m^2), mean weight (g) and mean biomass (g/m^2) of red sea urchins in British Columbia by statistical area, all years combined, obtained from broad-brush surveys during 1993 - 1997. Data include analyses from Jamieson et al. (1998a, b, c, d) and present study. Mean biomass = density x mean weight. 2E and 2W refer to east and west areas of statistical area 2 in the Queen Charlotte Islands.

[a] = sub-statistical area 12.014 not included.

Statarea	Year	Total Transect		Total Urchin			Percent Urchins		Number of Urchins Measured	Urchin density		Mean weight (g)		Mean biomass (g/m^2)	
		Number	Length (m)	Number	density mean	density se	≥ 100 mm TD	100 - 140 mm TD		≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD
North coast of B.C.															
1	94	45	7104	17082	2.405	0.498	55.27	50.96	2174	1.329	1.225	552.7	517.7	734.6	634.3
2E	93-95	78	10034	14038	1.399		33.95	32.62	3941	0.475	0.456	512.1	494.3	243.2	225.6
2W	93-95	63	4631	15226	3.288		20.19	19.15	3508	0.664	0.629	483.5	456.6	321.0	287.4
2	93-95	141	14665	29264	1.995		26.79	25.61	7449	0.535	0.511	500.8	479.6	267.8	245.1
3	93	35	1223	1746	1.428		47.37	44.25	1218	0.676	0.632	544.7	516.4	368.4	326.3
4	93-95	105	8343	10468	1.255		44.36	40.02	2924	0.557	0.502	557.1	510.0	310.0	256.1
5	97	56	6284	14038	2.234	0.339	48.21	42.13	2651	1.077	0.941	559.2	497.8	602.2	468.4
6	93-95	150	13214	33188	2.512		38.42	36.13	7324	0.965	0.907	513.5	484.9	495.5	440.0
7	93-97	365	56484	74219	1.314		35.61	34.86	14135	0.468	0.458	467.4	456.7	218.7	209.2
8	93	.					26.34	25.45	448			482.5	465.7		
10	93	5	2984	2097	0.703		12.35	12.23	826	0.087	0.086	438.0	431.0	38.0	37.0
106	94	28	2633	11970	4.546	0.703	38.79	37.90	1124	1.763	1.723	475.8	458.3	839.0	789.7
Total	93 - 97	850	107030	177179	1.655		37.84	35.84	34479	0.626	0.593	505.9	479.5	316.9	284.5
South coast of B.C.															
11	96	32	1360	4248	3.124	0.621	66.15	51.87	455	2.066	1.620	674.8	597.1	1394.4	967.4
12[a]	94-96	176	10864	11105	1.022	0.122	59.27	48.65	3333	0.606	0.497	631.1	556.6	382.3	276.8
12.014	96	8	809	4532	5.602	4.204	37.41	36.05	147	2.096	2.020	464.9	450.1	974.3	909.1
111	96	6	598	8180	13.679	2.376	30.26	29.74	380	4.140	4.068	452.6	444.7	1873.7	1809.1

Table 7. Red sea urchin bed areas (ha) for each statistical district estimated from digitized charts of beds indicated on fishers' log books for 1994 and 1996.
a = quarter of digitized shoreline in 0 - 9.1 m depth chart datum .
b = half of digitized shoreline of Cox Island in 0 - 9.1 m depth chart datum .

Statarea		Bed area (ha) 1994	Bed area (ha) 1996	Percent change
North Coast B.C.				
1		7006.1	9081.8	22.86
2E		3270.7	3733.7	12.40
2W		1062.5	2014.5	47.26
3		837.6	855.2	2.06
4		3665.7	4336.0	15.46
5		8224.9	10288.2	20.05
6		8298.7	10334.0	19.70
7		4349.6	5789.5	24.87
8a		202.6	340.9	40.57
9b		474.1	505.7	6.25
10		839.6	1040.8	19.34
105		0.0	56.9	100.00
106		1554.8	1827.9	14.94
	Total	39786.8	50205.2	20.75
South Coast - Inside Waters				
11		218.6	278.5	21.50
12		2034.4	2299.8	11.54
13		1245.4	1651.3	24.58
14		847.3	847.3	0.00
15		36.9	36.9	0.00
17		182.3	218.9	16.74
18		439.5	669.4	34.34
19		233.0	245.4	5.07
28		6.5	6.5	0.00
29		62.8	64.2	2.18
	Total	5306.8	6318.3	16.01
South Coast - WCVI				
20		459.0	499.2	8.05
23		185.7	256.6	27.63
24		550.0	799.3	31.19
25		601.6	602.6	0.17
26		37.8	37.8	0.00
27		393.4	467.0	15.77
124		0.0	2.8	100.00
125		54.9	54.9	0.00
	Total	2282.4	2720.2	16.10
South Coast all	Total	7589.1	9038.5	16.04
B.C. all	Total	47376.0	59243.6	20.03
South Coast - new				
12.014[a]			425.3	
111[b]			205.4	
	Total		630.7	

Table 8. Quota (tonnes) options for the red sea urchin fishery by statistical area, estimated from various natural mortality values applied to current biomass (Bc), mean biomass values (g/m^2) for commercial red sea urchin sizes ≥ 100 mm TD and 100 - 140 mm TD, and bed areas fished up to 1996.

a. Data not available for statarea so overall mean biomass for North Coast used (Table 6). b. Overall mean biomass was estimated from literature and recent surveys because up to date data for each statarea were not available. c. Beds (not fished before) estimated from digitized charts of shoreline for the 0-9 m depth range, 1701.5 ha / 4 for statarea 12.014, and 410.84 ha / 2 for statarea 111 (Cox Island only) to be conservative.

Statarea		Mean biomass (g/m^2)		Bed	Bc Biomass (t)		Quota 0.2 M Bc							
							M = 0.052		M = 0.075		M = 0.10		M = 0.15	
		≥ 100 mm TD	100 - 140 mm TD	area (ha) 1996	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD
North Coast B.C.														
1		734.6	634.3	9081.8	66711.6	57607.1	693.8	599.1	1000.7	864.1	1334.2	1152.1	2001.3	1728.2
2E		243.2	225.6	3733.7	9082.2	8422.4	94.5	87.6	136.2	126.3	181.6	168.4	272.5	252.7
2W		321.0	287.4	2014.5	6465.9	5789.7	67.2	60.2	97.0	86.8	129.3	115.8	194.0	173.7
3		368.4	326.3	855.2	3150.4	2790.3	32.8	29.0	47.3	41.9	63.0	55.8	94.5	83.7
4		310.0	256.1	4336.0	13442.9	11102.7	139.8	115.5	201.6	166.5	268.9	222.1	403.3	333.1
5		602.2	468.4	10288.2	61959.4	48194.7	644.4	501.2	929.4	722.9	1239.2	963.9	1858.8	1445.8
6		495.5	440.0	10334.0	51203.4	45469.6	532.5	472.9	768.1	682.0	1024.1	909.4	1536.1	1364.1
7		218.7	209.2	5789.5	12662.2	12110.1	131.7	125.9	189.9	181.7	253.2	242.2	379.9	363.3
8	a	316.9	284.5	340.9	1080.2	969.8	11.2	10.1	16.2	14.5	21.6	19.4	32.4	29.1
9	a	316.9	284.5	505.7	1602.6	1438.8	16.7	15.0	24.0	21.6	32.1	28.8	48.1	43.2
10		38.0	37.0	1040.8	395.6	385.4	4.1	4.0	5.9	5.8	7.9	7.7	11.9	11.6
105	a	316.9	284.5	56.9	180.3	161.8	1.9	1.7	2.7	2.4	3.6	3.2	5.4	4.9
106		839.0	789.7	1827.9	15335.5	14434.2	159.5	150.1	230.0	216.5	306.7	288.7	460.1	433.0
			Total	50205.2	243272.2	208876.5	2530.0	2172.3	3649.1	3133.1	4865.4	4177.5	7298.2	6266.3
South Coast - Inside Waters														
11		1394.4	967.4	278.5	3883.7	2694.4	40.4	28.0	58.3	40.4	77.7	53.9	116.5	80.8
12		423.4	320.6	2299.8	9736.7	7374.0	101.3	76.7	146.0	110.6	194.7	147.5	292.1	221.2
13	b	681.8	589.0	1651.3	11257.6	9726.5	117.1	101.2	168.9	145.9	225.2	194.5	337.7	291.8
14	b	681.8	589.0	847.3	5776.3	4990.7	60.1	51.9	86.6	74.9	115.5	99.8	173.3	149.7
15	b	681.8	589.0	36.9	251.7	217.5	2.6	2.3	3.8	3.3	5.0	4.3	7.6	6.5
17	b	681.8	589.0	218.9	1492.5	1289.5	15.5	13.4	22.4	19.3	29.8	25.8	44.8	38.7
18	b	681.8	589.0	669.4	4563.6	3943.0	47.5	41.0	68.5	59.1	91.3	78.9	136.9	118.3
19	b	681.8	589.0	245.4	1673.0	1445.5	17.4	15.0	25.1	21.7	33.5	28.9	50.2	43.4
28	b	681.8	589.0	6.5	44.2	38.2	0.5	0.4	0.7	0.6	0.9	0.8	1.3	1.1

Table 8. Quota (tonnes) options for the red sea urchin fishery by statistical area, estimated from various natural mortality values applied to current biomass (Bc), mean biomass values (g/m^2) for commercial red sea urchin sizes ≥ 100 mm TD and 100 - 140 mm TD, and bed areas fished up to 1996.

a. Data not available for statarea so overall mean biomass for North Coast used (Table 6). b. Overall mean biomass was estimated from literature and recent surveys because up to date data for each statarea were not available. c. Beds (not fished before) estimated from digitized charts of shoreline for the 0-9 m depth range, 1701.5 ha / 4 for statarea 12.014, and 410.84 ha / 2 for statarea 111 (Cox Island only) to be conservative.

Statarea		Mean biomass (g/m^2)		Bed	Bc Biomass (t)		Quota 0.2 M Bc							
							M = 0.052		M = 0.075		M = 0.10		M = 0.15	
		≥ 100 mm TD	100 - 140 mm TD	area (ha) 1996	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD	≥ 100 mm TD	100 - 140 mm TD
29	b	681.8	589.0	64.2	438.0	378.4	4.6	3.9	6.6	5.7	8.8	7.6	13.1	11.4
			Total	6318.3	39117.3	32097.6	406.8	333.8	586.8	481.5	782.3	642.0	1173.5	962.9
South Coast - WCVI														
20	b	681.8	589.0	499.2	3403.3	2940.4	35.4	30.6	51.0	44.1	68.1	58.8	102.1	88.2
23	b	681.8	589.0	256.6	1749.6	1511.7	18.2	15.7	26.2	22.7	35.0	30.2	52.5	45.4
24	b	681.8	589.0	799.3	5449.1	4708.0	56.7	49.0	81.7	70.6	109.0	94.2	163.5	141.2
25	b	681.8	589.0	602.6	4108.2	3549.5	42.7	36.9	61.6	53.2	82.2	71.0	123.2	106.5
26	b	681.8	589.0	37.8	257.7	222.7	2.7	2.3	3.9	3.3	5.2	4.5	7.7	6.7
27	b	681.8	589.0	467.0	3183.8	2750.8	33.1	28.6	47.8	41.3	63.7	55.0	95.5	82.5
124	b	681.8	589.0	2.8	18.8	16.3	0.2	0.2	0.3	0.2	0.4	0.3	0.6	0.5
125	b	681.8	589.0	54.9	374.4	323.5	3.9	3.4	5.6	4.9	7.5	6.5	11.2	9.7
			Total	2720.2	18545.0	16022.8	192.9	166.6	278.2	240.3	370.9	320.5	556.3	480.7
South Coast all			Total	9038.5	57662.2	48120.4	599.7	500.5	864.9	721.8	1153.2	962.4	1729.9	1443.6
B.C. all			Total	59243.6	300934.5	256996.9	3129.7	2672.8	4514.0	3855.0	6018.7	5139.9	9028.0	7709.9
South Coast - new														
12.014	c	974.3	909.1	425.3	4143.7	3866.4	43.1	40.2	62.2	58.0	82.9	77.3	124.3	116.0
111	c	1873.7	1809.1	205.4	3848.5	3715.8	40.0	38.6	57.7	55.7	77.0	74.3	115.5	111.5
			Total	630.7	7992.2	7582.2	83.1	78.9	119.9	113.7	159.8	151.6	239.8	227.5
B.C. all + new			Total	59874.3	308926.7	264579.1	3212.8	2751.6	4633.9	3968.7	6178.5	5291.6	9267.8	7937.4

Fig. 1. Location of general coastal regions where red sea urchins are picked and study areas in British Columbia. South Coast regions: WCVI, west coast of Vancouver Island; I.W., Inside Waters. Study areas: C, Campbell River; T, Tofino.

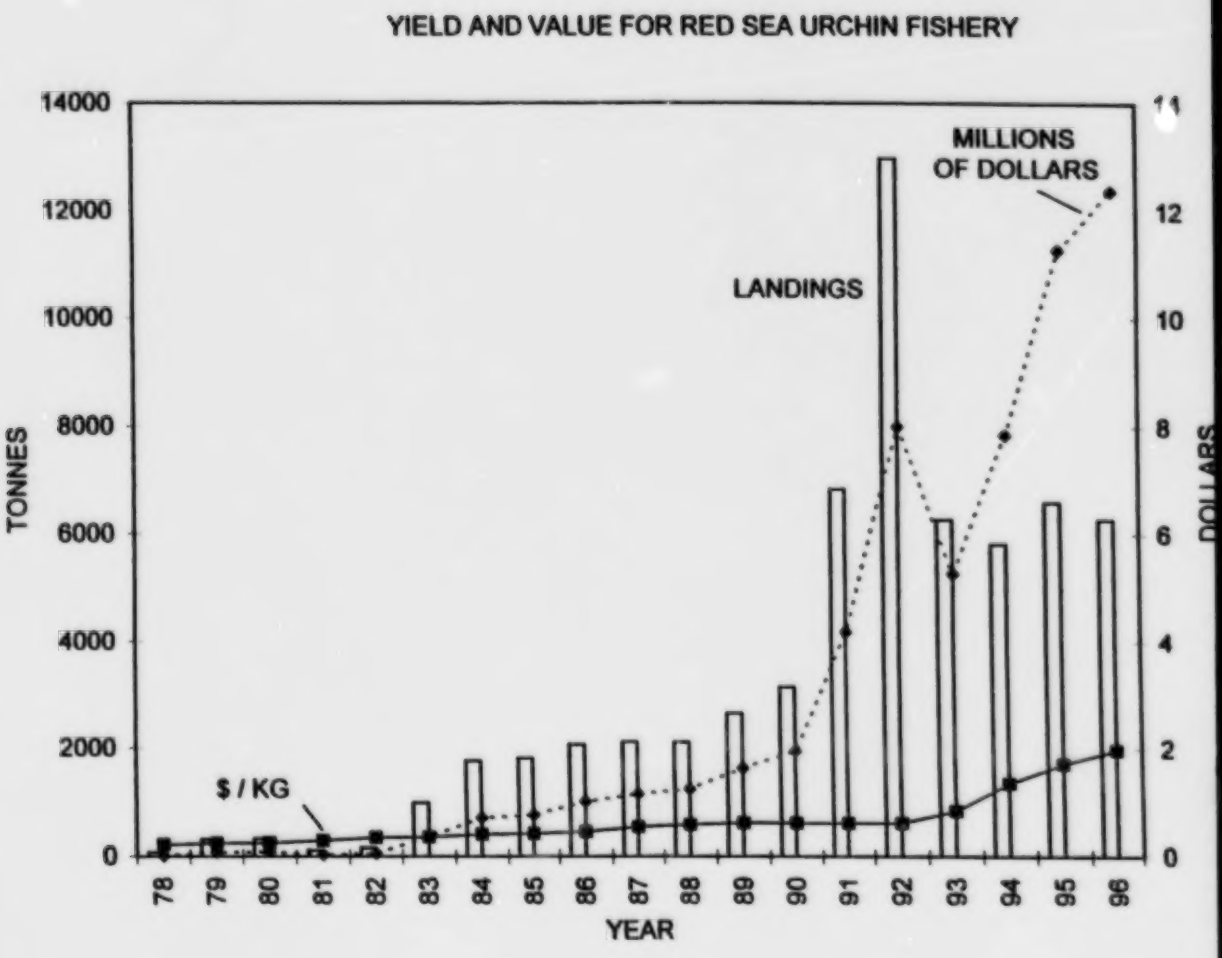


Fig. 2. Annual yield and value for the red sea urchin fishery in British Columbia, 1978-96.

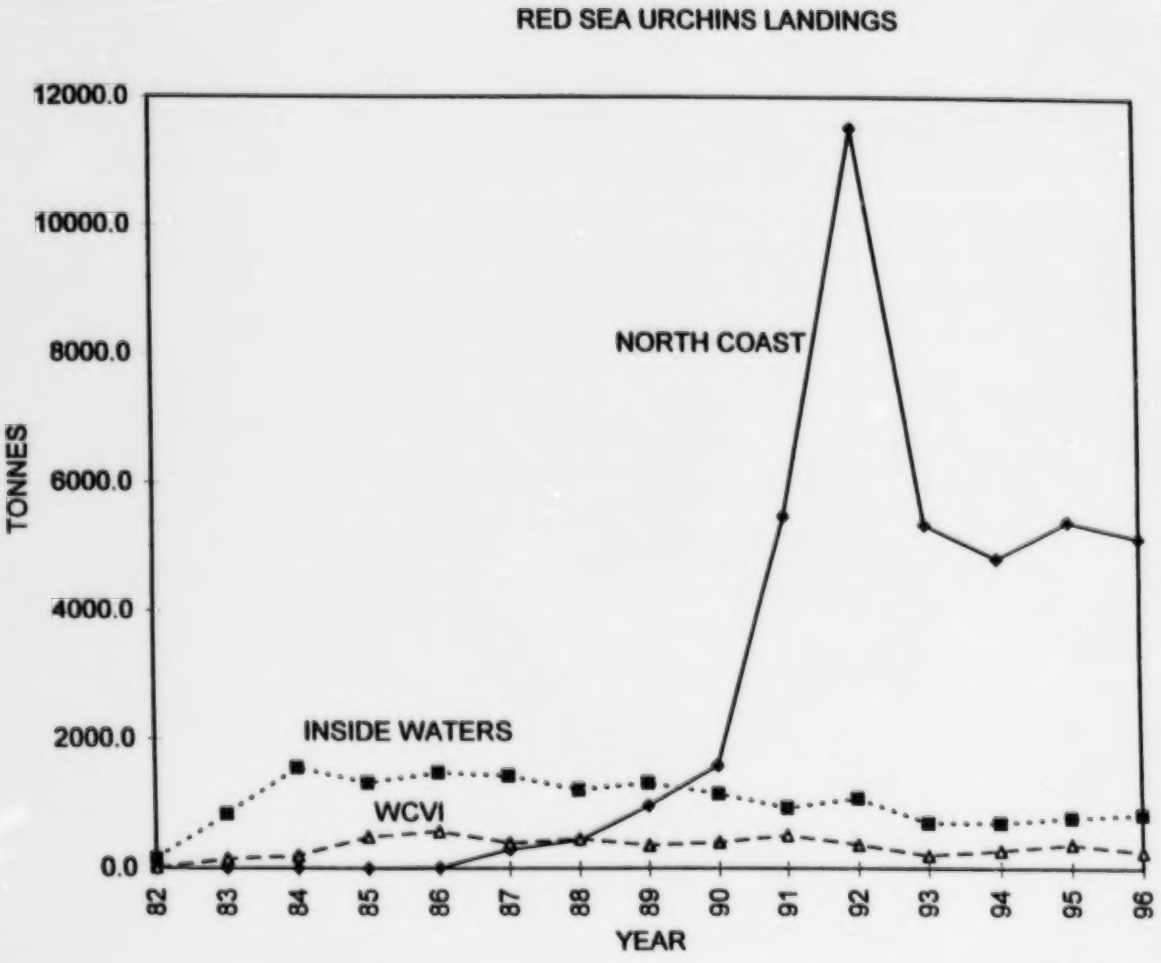


Fig. 3. Annual landings in tonnes for the North Coast (diamond), South Coast - Inside Waters (square) and WCVI (triangle) from sales slips, 1982-96.

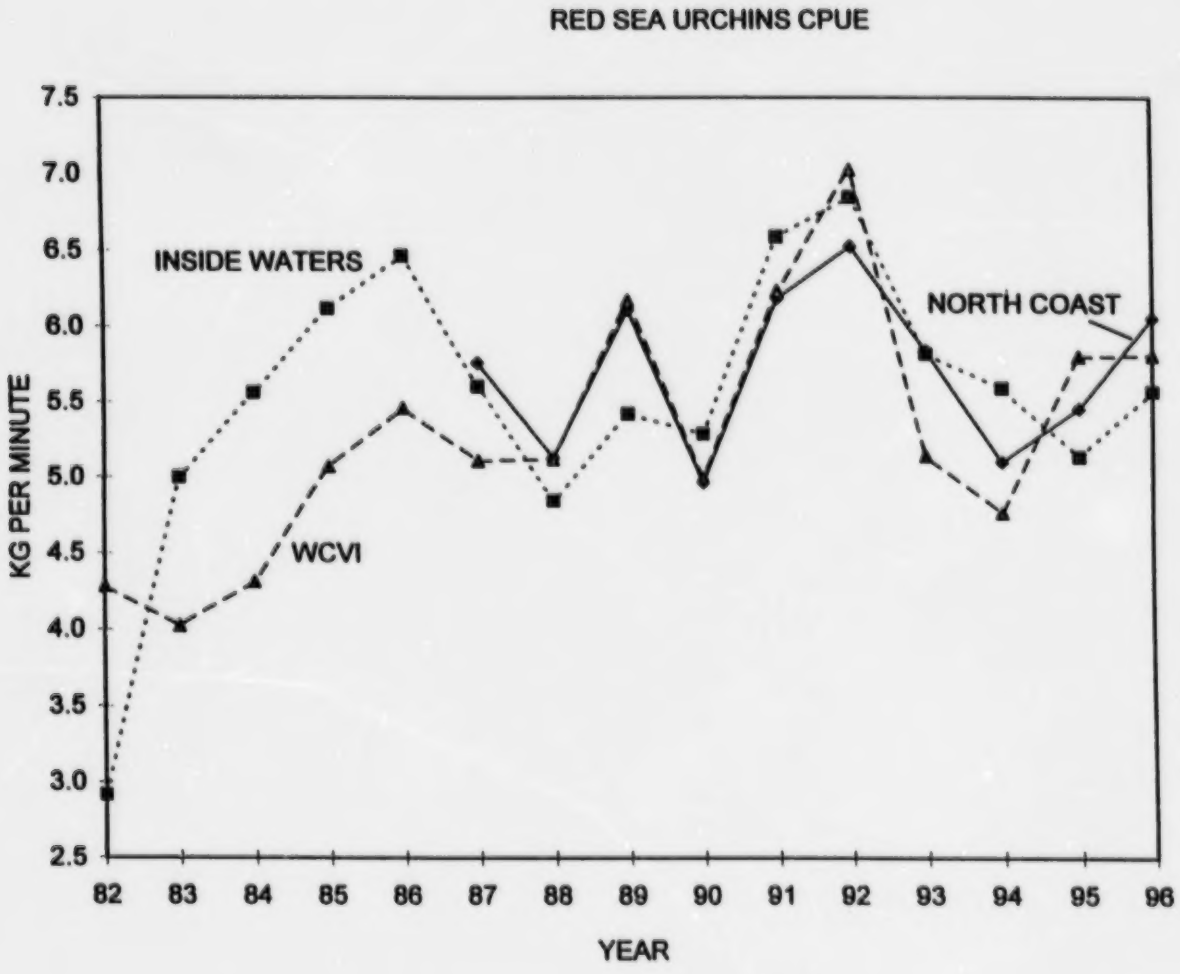
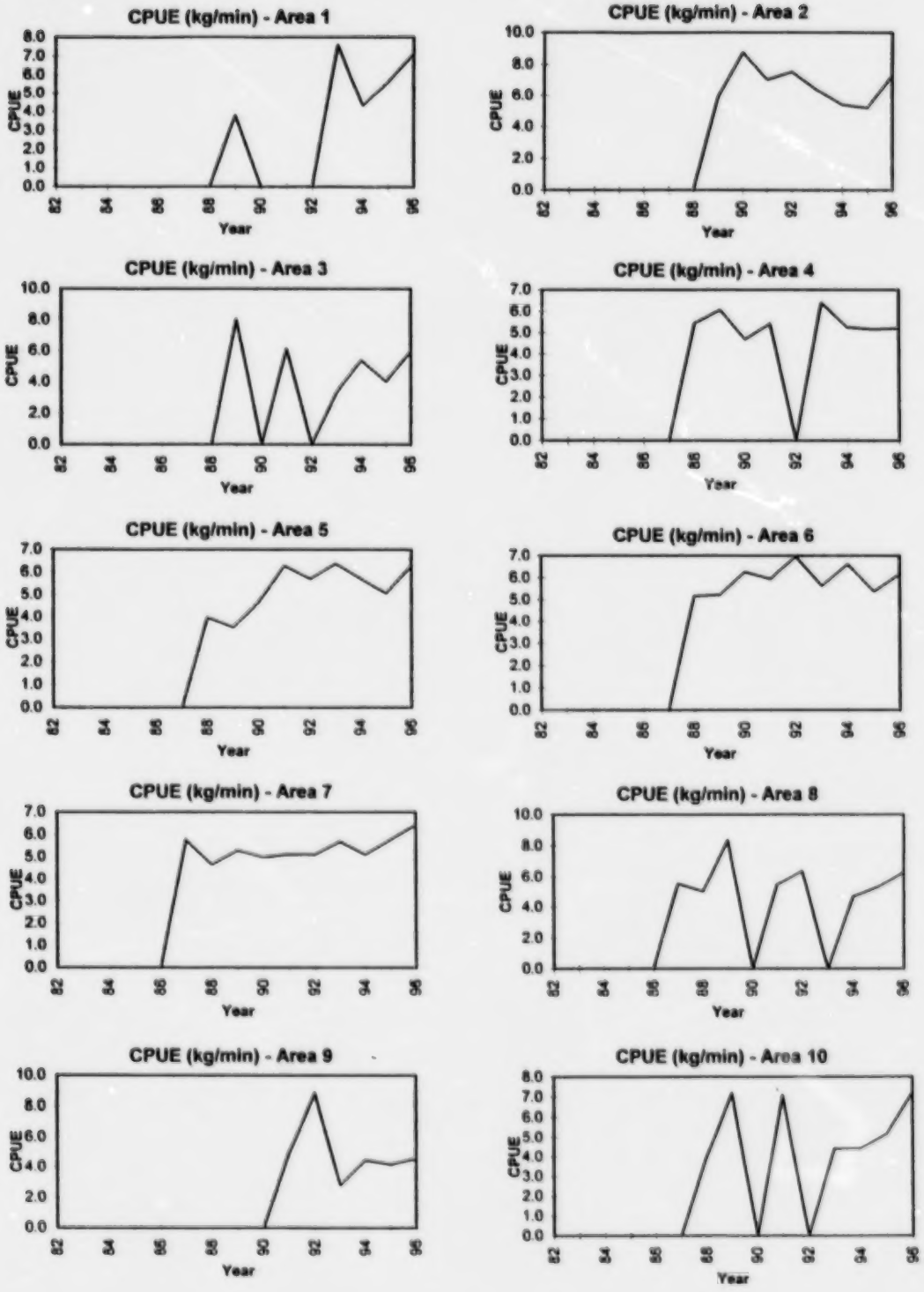


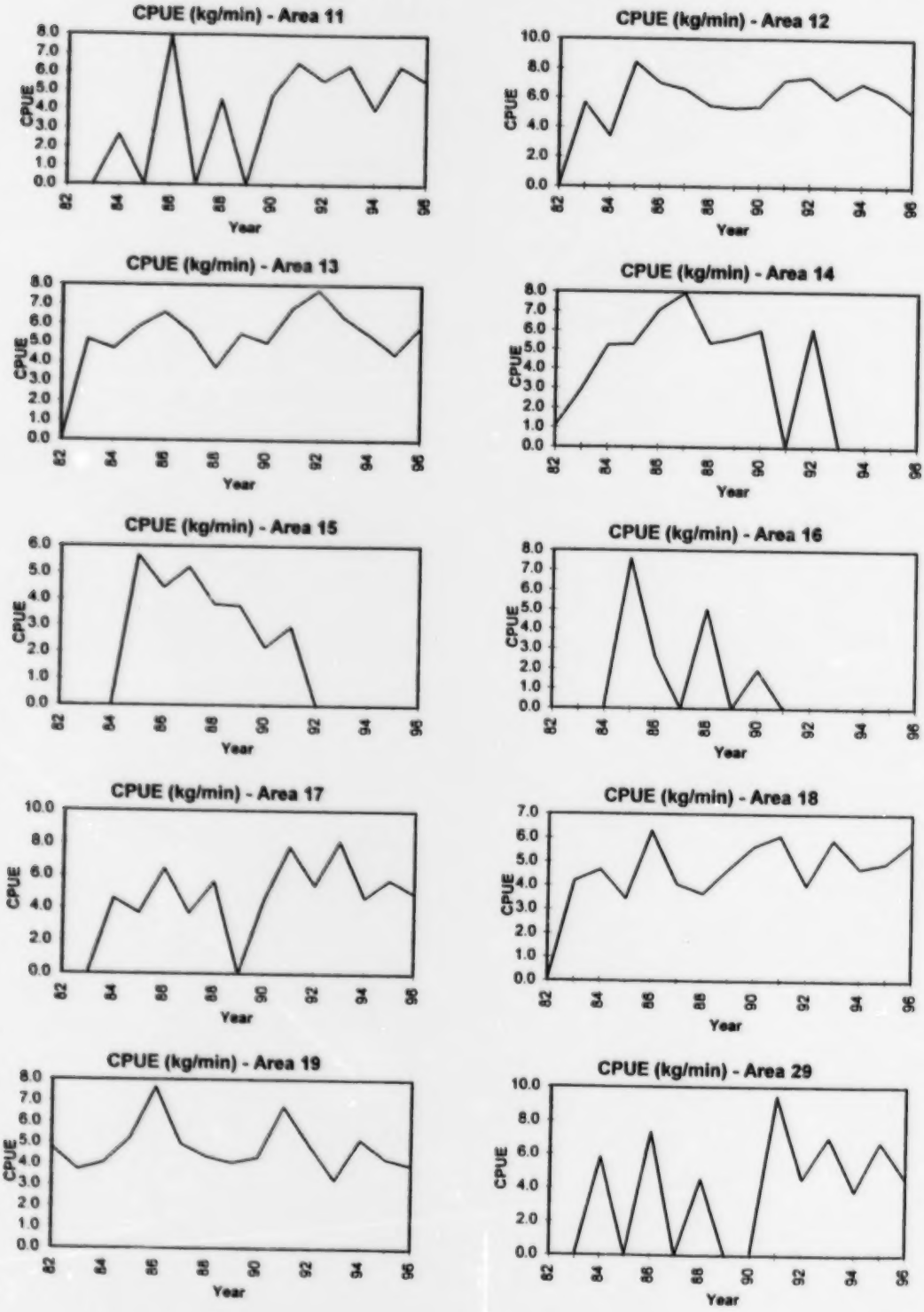
Fig. 4. Annual mean CPUE (kilograms per diver minute) from harvest logbooks for the North Coast (diamond), South Coast - Inside Waters (square) and WCVI (triangle).

NORTH COAST



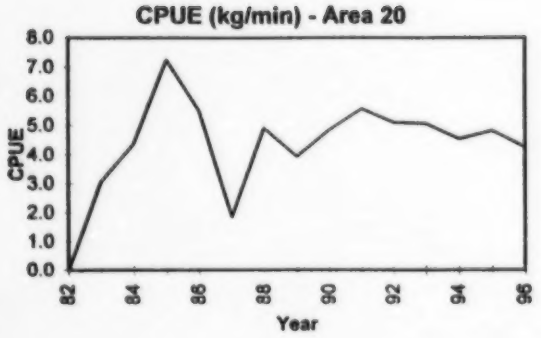
Appendix 1a. Mean annual CPUE (kilograms per diver minute) of red sea urchins for each statistical area in the North Coast. Data from harvest logbooks.

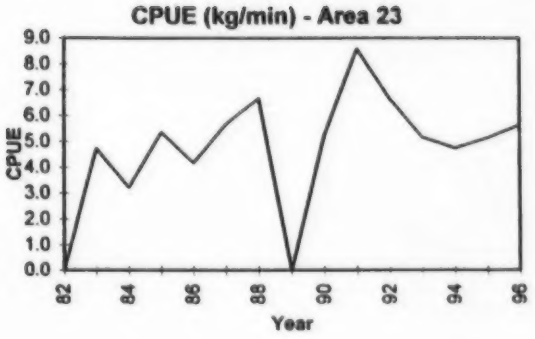
INSIDE WATERS

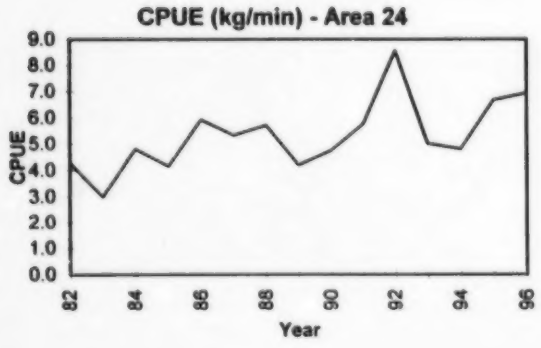


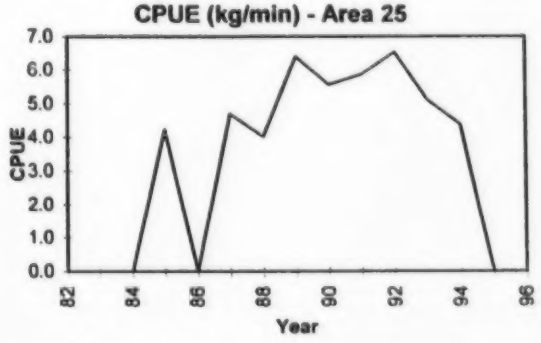
Appendix 1b. Mean annual CPUE (kilograms per diver minute) of red sea urchins for each statistical area in the Inside Waters. Data from harvest logbooks.

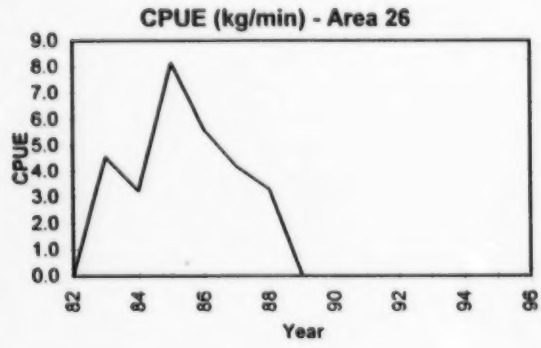
WCVI

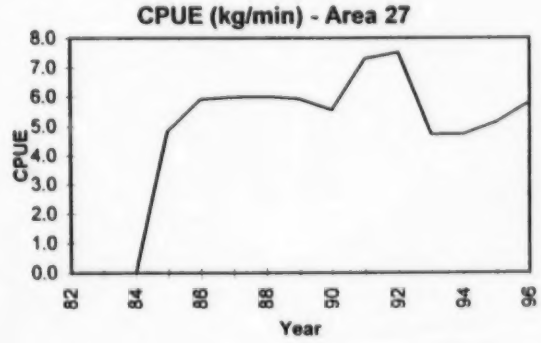












Appendix 1c. Mean annual CPUE (kilograms per diver minute) of red sea urchins for each statistical area in the WCVI. Data from harvest logbooks.